Spatial Analysis and Design for Sustainable Urban Development Using Remote Sensing and GIS Techniques

1 Introduction

The world's population is going toward urbanization progressively more; in such a way that since the early 21st century (2008) onward, more than half of the world's population will live in urban regions. Regarding this flow, it is projected that more than 65 % of world's population are going to live in urban areas by 2025; it means these are locations, which consume most resources and produce most wastes and pollutions. According to speed of urbanization, urban environments will replace natural ecosystems and this expedite urbanization leads to increasing urban problems and social, economical and environmental inequalities; and its consequences are increasing poverty in cities, environmental pollutions, shortage of urban services and water sources and spreading suburbanization. The consequences of expedite urbanization are increasing challenges and social, economical and environmental inequalities in urban regions of under developing countries and urbanization created an extensive domain of heterogeneous conditions (Masoud Taghvaei, 2016).

1.1 Remote Sensing

Remote sensing is defined as the science of identifying, measuring and analyzing the characteristics of objects of interest without actually being in contact with them. It is done by sensing and recording the energy reflected or emitted by these objects and then processing and interpreting that information. Remote sensing makes use of the fact that every object has a unique characteristic reflection and emission spectra that can be utilized to identify that object. Sometimes, the gravitational and magnetic fields are also employed for remote sensing applications. One of the potential advantages that this technology offers is that through it various observations can be made, measurements taken and images of phenomena produced that are beyond the limits of normal perception.

Remote sensing is widely used by biologists, geologists, geographers, agriculturists, foresters and engineers to generate information on objects on Earth’s land surface, oceans and atmosphere. Applications include monitoring natural and agricultural resources,

assessing crop inventory and yield, locating forest fires and assessing the damage caused, mapping and monitoring of vegetation, air and water quality, etc.

Satellites are the main remote sensing platforms used today and are sometimes referred to as 'eyes in the sky'. Use of satellites for remote sensing applications has brought a revolution in this field as they can provide information on a continuous basis of vast areas on the Earth's surface day and night. Constellations of satellites continuously monitor Earth and provide even minute details of the Earth's surface. This ever-expanding range of geographical and geophysical data help people to understand their planet better, monitor various parameters more minutely and hence manage and solve the problems related to Earth more efficiently. Satellites have become the main platform for carrying out remote sensing activities as they offer a number of advantages over other platforms.

Some of these advantages include:

1. Continuous acquisition of data
2. Frequent and regular re-visit capabilities resulting in up-to-date information
3. Broad coverage area
4. Good spectral resolution
5. Semi-automated/computerized processing and analysis
6. Ability to manipulate/enhance data for better image interpretation
7. Accurate data mapping

1.2 Geographic Information System

The geographic information system (GIS) is a computer-based information system used to digitally represent and analyse the geographic features present on the Earth's surface.

The GIS performs the following three main functions:

1. To store and manage geographic information comprehensively and effectively.
2. To display geographic information depending on the purpose of use.
3. To execute query, analysis and evaluation of geographic information effectively.

The GIS uses the remote sensing data either as classified data or as image data. Land cover maps or vegetation maps classified from remote sensing data can be overlaid on to other

geographic data, which enables analysis for environmental monitoring and its change. Remote sensing data can be classified or analysed with other geographic data to obtain a higher accuracy of classification. Using the information available in maps like the ground height and slope gradient information, it becomes easier to extract relevant information from the remote sensing images.

2. Previous work on urban development:

In this section we discuss three different study approaches, based on (i) Quantitative model of TOPSIS (ii) Cellular automaton model and (iii) Remote Sensing and Geographic Information Systems.

(i) Quantitative model of TOPSIS:

Spreading cities and increasing urban population scaled up urban problems and challenges. As a metropolis, Isfahan is faced with many challenges, too, which requires effective and qualitative urban development plans in regards of urban sustainable development structure in order to improving itself. The objective of this research is evaluating status of sustainable development of Isfahan and effect of urban development plan on this city. Therefore, the research data is analyzed and evaluated using quantitative model of TOPSIS regarding objectives and hypotheses of the research. In addition, Entropy and coefficient of dispersion, SPSS, EXCEL and TOPSIS SOLVER software are used in order to dada analysis and ARC GIS software is used to draw and provide maps. Results and findings of analyzing and evaluating this research indicated that urban development flow of Isfahan is an unsustainable flow at both levels of "present situation" and "urban development plan"; most districts in Isfahan are much less prosperous, less prosperous or fairly prosperous. Therefore, in "current condition", 33% of urban district in Isfahan are at "less prosperous and much less prosperous" level and 37% of districts are at "fairly prosperous" level; only 30% of urban district in Isfahan are at "prosperous and very prosperous" level. This condition deteriorated more in urban development plan. In urban development plan of Isfahan, 55% of urban district of this city are at "less prosperous and much less prosperous" level and 15% of districts are at "fairly prosperous" level; only 30% of urban districts of Isfahan are at "very prosperous and prosperous" level. According to this fact that indicatives of this analysis are

capitations of urban services' applications, we can conclude that capitation of urban services' applications is reduced in urban development plan and is turned to capitation of residential applications (non-service). Therefore, metropolis of Isfahan is not a sustainable and prosperous city and facilities or public services are not distributed sustainably and concordantly in its urban districts. (Masoud Taghvaei, Hamid Reza Varesi & Masoud Narimani, 2016)

(ii) Cellular automaton model:

Prior research developed a cellular automaton model, which was calibrated by using historical digital maps of urban areas and can be used to predict the future extent of an urban area. The model has now been applied to two rapidly growing, but remarkably different urban areas: the San Francisco Bay region in California and the Washington/Baltimore corridor in the Eastern United States. This paper presents the calibration and prediction results for both regions, reviews their data requirements, compares the differences in the initial configurations and control parameters for the model in the two settings, and discusses the role of GIS in the applications. The model has generated some long term predictions that appear useful for urban planning and are consistent with results from other models and observations of growth. Although the GIS was only loosely coupled with the model, the model's provision of future urban patterns as data layers for GIS description and analysis is an important outcome of this type of calculation. (K. C. Clarke and L. J. Gaydos, 1998)

(iii) Remote Sensing and Geographic Information Systems:

Irregular and exponential growth of urban/suburban commercial and residential zones has resulted in improper and irreversible land transformation and use. The lack of data regarding the driving forces to sprawl and densification of suburban areas, identification of the pressures created by unplanned sprawl over time and inadequate information to measure, monitor and understand the sprawl and structure of a demography has resulted in an imbalanced sustainable development leading to numerous adverse impacts on a demography's natural, human, physical, social and financial capital. In the present study, patterns of spatiotemporal growth, sprawl and structure of three cities, namely, Rajkot, Surat and Vadodara (Gujarat-India) were studied over the past decade with the help of Remote

Sensing and Geographic Information Systems. Ground surveys regarding the inferences from the processed GIS images were performed in order to understand the impacts of climate change on health and economy, due to non monitored urban sprawl over the past decade. The driving forces to the sprawl have been accounted and related to the financial development of the cities over time of study. The temporal pressures hence created have been related to resultant impacts of climate change due to improper environmental planning and management. The study also compares the growth rate and sprawl patterns of the three cities on the basis of Sustainability Pentagon Analysis, by distributing relatively equal weights to the driving forces of the change in urban structure and their resultant effects. It ultimately suggests the ways in which the sprawl of urban and suburban centers of the cities could be planned and moderated for achieving sustainable development. (Madhuri Kumari and Nishant Joshi, 2015)

3. Problem Statement

The population of the world is on the verge of shifting from being predominantly rural to urban. As of 2008, more than half of the world's human population has resided in urban areas, and by 2030, urban inhabitants will account for approximately 60% of the world's population (Waibel, 1995). Urbanization can be defined as the changes that occur in the territorial and socioeconomic progress of an area, including the general transformation of land cover/use categories from being non-developed to developed (Weber, 2001). The rapid growth of the urban population has occurred in response to increased urban migration as people search for better jobs and improved living conditions. Historically, urban immigration has increased at rates that have exceed those of infrastructure development in the destination cities, resulting in immigrants being unable to find suitable employment opportunities and subsequently becoming part of the urban poor. This rapid increase in urbanization and the concomitant effect that it has on land use means that it is becoming increasingly for city planners to adopt appropriate sustainable land use plans.

Planning and managing urban spaces depends on knowledge of the underlying driving forces, combined with the chronology and impacts of urbanization (Klosterman, 1999). City planners, economists and resource managers therefore need advanced methods and a comprehensive knowledge of the cities under their jurisdiction to make the informed

decisions necessary to guide sustainable development in rapidly changing urban environments. Remote sensing provides spatially consistent coverage of large areas with both high spatial detail and temporal frequency, which is useful for examining historical time series (Jensen and Cowen, 1999). Moreover, remote sensing data is effective to monitor the land use change in areas, especially where information on land use management is inconsistent and insufficient.

For example, recently the economic development in Hanoi impacts the land use change in the suburb occurring rapidly. With the current land use map is updated every 5 years, local land use managers have not enough information to monitor land use change of Hanoi. Therefore, with increased availability and improved multi-spatial and multi-temporal resolution, remote sensing can now be applied to monitor and analyse urban expansion and land use changes in a timely and cost-effective manner.

So it is required to study existing local participatory plan of regional development, to specify innovative strategies for sustainable development of the region. And try to prepare geospatial data for sustainable regional planning using Remote Sensing (RS) and Geographic Information System (GIS).

Thus we decided to work on to apply remote sensing & geographical information system for the effective solutions of the urbanization problems in some cities.

4. Research Objectives

The main objective of this study is to develop and test remote sensing and geographical information system based methods for sustainable urban development.

To achieve this objective, the following specific objectives have been defined

1. To examine existing urban development strategies of the region.
2. To prepare geospatial database for sustainable urban planning.
3. To specify strategies for sustainable development of the region.

5. Research Methodology

The research is composed of three main parts, showing a methodological development of a bottom-up planning from the *terroir* to the regional level (Fig. 1).

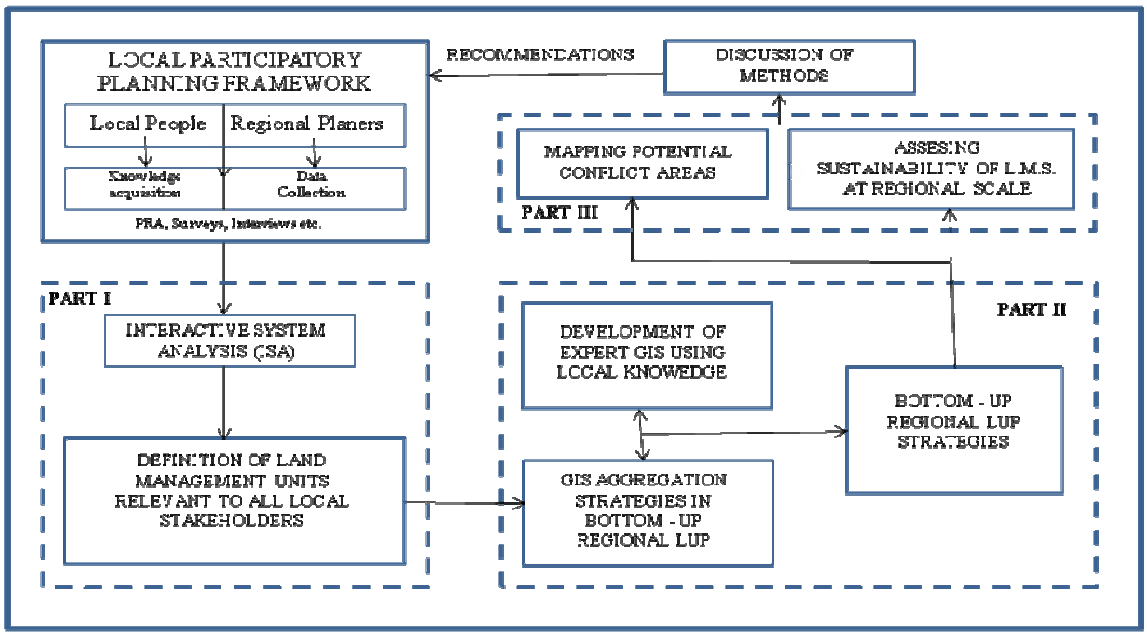
LOCAL PARTICIPATORY PLANNING FRAMEWORK
Local People
Regional Planers
Knowledge acquisition
Data Collection
PRA, Surveys, Interviews etc.
RECOMMENDATIONS
DISCUSSION OF METHODS
MAPPING POTENTIAL CONFLICT AREAS
ASSESSING SUSTAINABILITY OF L.M.S. AT REGIONAL SCALE
PART III
PART I
INTERACTIVE SYSTEM ANALYSIS (ISA)
DEFINITION OF LAND MANAGEMENT UNITS RELEVANT TO ALL LOCAL STAKEHOLDERS
PART II
DEVELOPMENT OF EXPERT GIS USING LOCAL KNOWEDGE
BOTTOM - UP REGIONAL LUP STRATEGIES
GIS AGGREGATION STRATEGIES IN BOTTOM - UP REGIONAL LUP

Figure 1 : Flow diagram of research methodology.

References

Masoud Taghvaei, Hamid Reza Varesi & Masoud Narimani An Analysis on Effect of Urban Development Plans on Realization of Sustainable Development of Metropolis of Isfahan Modern Applied Science; Vol. 10, No. 3; 2016

*K. C. Clarke and L . J. Gaydos, 1998)*Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore, int. j. geographical information science, 1998, vol. 12, no. 7, 699± 714

Madhuri Kumari and Nishant Joshi, Spatiotemporal Analysis of Urban Growth, Sprawl and Structure of Rajkot, Vadodara and Surat (Gujarat-India) based on Geographic Information Systems, in Relation to the Sustainability Pentagon Analysis, Indian Journal of Science and Technology, Vol 8(28), DOI10.17485/ijst/2015/v8i28/83639. October 2015

Waibel, M., 1995. Drawn and quartered–Hanoi's ancient centre is feeling the pressure from outside and in, So what can architects and officials do to stop the rot? Vietnam Econ. Times., 24–25.

Weber, C., 2001. Remote sensing data used for urban agglomeration delimitation. Remote Sens. Urban Anal., 155–167.

Klosterman, R.E., 1999. TheWhatif? Collaborative planning support system. Environ. Plann. B 26, 393–408.

Jensen, J.R., Cowen, D.C., 1999. Remote sensing of urban/suburban infrastructure and socio-economic attributes. Photogramm. Eng. Rem. Sens. 65, 611–622.

Research Guide

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